

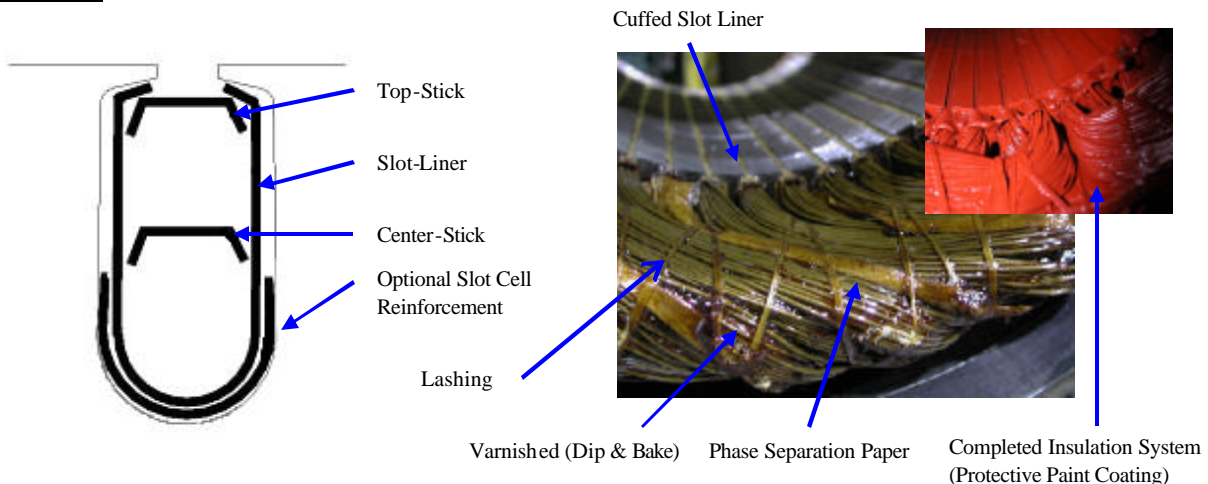
APPLICATION GUIDELINE #37

(Important Features of Stator Slot Insulation Systems)

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A very important consideration in the application of Variable Frequency Drives (VFD's) on motors is that of voltage stress on motor winding insulation. VFD's manufacture the AC output waveform from a DC source (which has usually been derived from the incoming AC power source). The inversion from DC to AC is generally accomplished by semiconductor switching devices, some of which may have very fast rise times (i.e.: high dV/dt). This high dV/dt spike/waveform stresses motor insulation, and is increased by large amounts of capacitance, such as from long cable lengths between the motor and the drive. It is important that the VFD manufacturer be aware of the consequences of voltage stress on motor insulation life, so that semiconductor rise times, carrier frequencies, cable lengths, filtering, etc. may all be considered in the design of VFD's. *Similarly, it is also very important that motor manufacturers be aware of the consequences of voltage stress on motor insulation, so that the best possible materials and care in manufacturing techniques are employed to ensure reliable operation of the motor.*

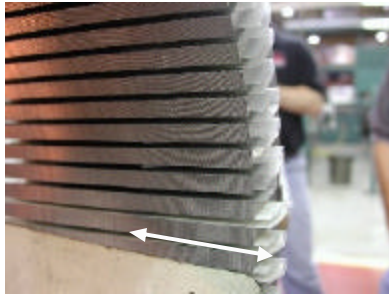
A quality built Random Wound motor stator slot insulation system consists of the following components:



- **Magnet wire** has a thin coating of insulation over round copper conductors, the insulation coating acts as turn to turn insulation. New coatings in development by quality wire manufacturers provide higher dielectric strengths at higher operating temperatures without affecting coating thickness. Thickness is critical so as not to affect motor performance, motor manufacturers need to obtain a certain number of turns in a given stator slot area. Toshiba uses a recently developed and fully tested thermaleze® Q^s 'tough wire' (Quantumshield magnet wire by Phelps Dodge). This new, 200°C rated insulation improves turn to turn insulation characteristics which allows the Toshiba insulation system to meet the new NEMA MG1 Section 31 requirements of 3.1 x rated voltage @ 0.1µs rise time.
- **Slot-liners** act as insulation from the stator steel which is at ground potential. Quality insulation systems will use materials such as Nomex or a Nomex-Mylar-Nomex sandwich. The Nomex material has a high temperature class rating, Class H (180°C), whereas the mylar rated as Class F (155°C) is inserted for it's strong mechanical features.

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- **Top-sticks** prevent the wires near the top of the slot from coming into contact with the stator steel, which is grounded. Quality insulation systems will also use materials such as Nomex or Nomex-Mylar-Nomex sandwich.
- **Center-sticks** are used with lap wound motors, and they insulate one winding from another. Quality insulation systems use materials such as Nomex or Nomex-Mylar-Nomex sandwich.
- **Slot Cell Reinforcement** adds mechanical strength to the slot liner insulation. This slot cell reinforcement is not commonly used due to costs, however is very strongly recommended to mechanically protect the end turn windings from being damaged when the end turns are “formed” with rubber mallets by the winders. Toshiba has recognized the benefits of this added reinforcement and therefore mylar inserts are added at the end of the slots as a standard feature.



- **Phase Separation Paper** is used to keep a good dielectric barrier between separate phases. Quality insulation systems use materials such as Nomex to accomplish this.
- **Lashing (end winding bracing)** is used to prevent movement in the end turns. It is important to make the end turns as close to a solid mass as possible. High speed photography of end turns during a start reveals that flexing can occur during a full voltage start. If this happens, the individual windings can rub and damage the turn to turn insulation resulting in a premature failure. Furthermore, the solid bracing of end windings is important on VFD applications due to the vibrations caused by PWM signals constantly bombarding the windings. Quality/reputable manufacturers use heat shrink type lashing material which optimally tightened when it is heated before the varnishing process. This is also a Toshiba standard lashing material.
- **Varnish** provides additional insulating properties plus mechanical strength. Once the windings have been installed in the stator and the end turns properly lashed, the complete stator is heated then submerged in heated varnish. The varnish flows into the windings and fills any voids between the magnet wire. Additional dips are performed which help to make the winding assembly a solid mass that will not flex during stresses at startup or during rapid load swings.

Do you know what you are getting?

Many EASA (Electrical Apparatus and Service Association) member shops use the latest and best materials available. However, it is prudent to ask a service shop what types of material are used for phase, slot liner insulation and lashing material. Products such as Nomex and Nomex/Mylar/Nomex sandwich for phase and slot liner insulation have excellent thermal aging properties. Nomex is a class H insulation with extremely good insulation characteristics, Mylar is extremely tough mechanically and has excellent dielectric properties which are important for PWM voltage spiking considerations, and therefore afford long life. Check with the service shop and/or motor manufacturer and ask what they use.

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